Sixth Annual Conference on Carbon Capture & Sequestration

Retrofitting of Existing Coal-Fired Plants

Retrofitting capture to capture-ready pulverized coal plants: the benefits of flexibility

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Interests and requirements for capture ready

Must:

Society

Reasonably-justified plan for the future

- Have access to geological storage
- Have space and access for capture equipment
- Have reasonable confidence it will work

e.g. Have to re-permit for CO_2 after ten years?

~~Also~~ Must consider:

Regulator — **but different interests?** — **Owner**

- Up-front expenditure with savings later, e.g.
  - IGCC instead of PC?
  - Bigger, better equipment?
  - Cheaper/better CO_2 storage?

& auditors, bank's engineers etc.

Detailed studies for immediate action, protect investment value

Capture-ready

The way plant is built and sited when it only has a temporary permit to emit CO_2

Flexibility, for post-combustion capture on PC plants:

a) When capture is added, timing not critical:

- minimal up-front expenditure to recover
- can build while plant is running,
- final connections during short outage
- can run without capture while commissioning

b) What capture technology can be added:

- space on site, including for construction
- tie-ins for flue gas, steam etc.
- good FGD
- flexible steam cycle

Can fit most likely post-combustion systems, use latest technology

c) How plant can be operated with capture:

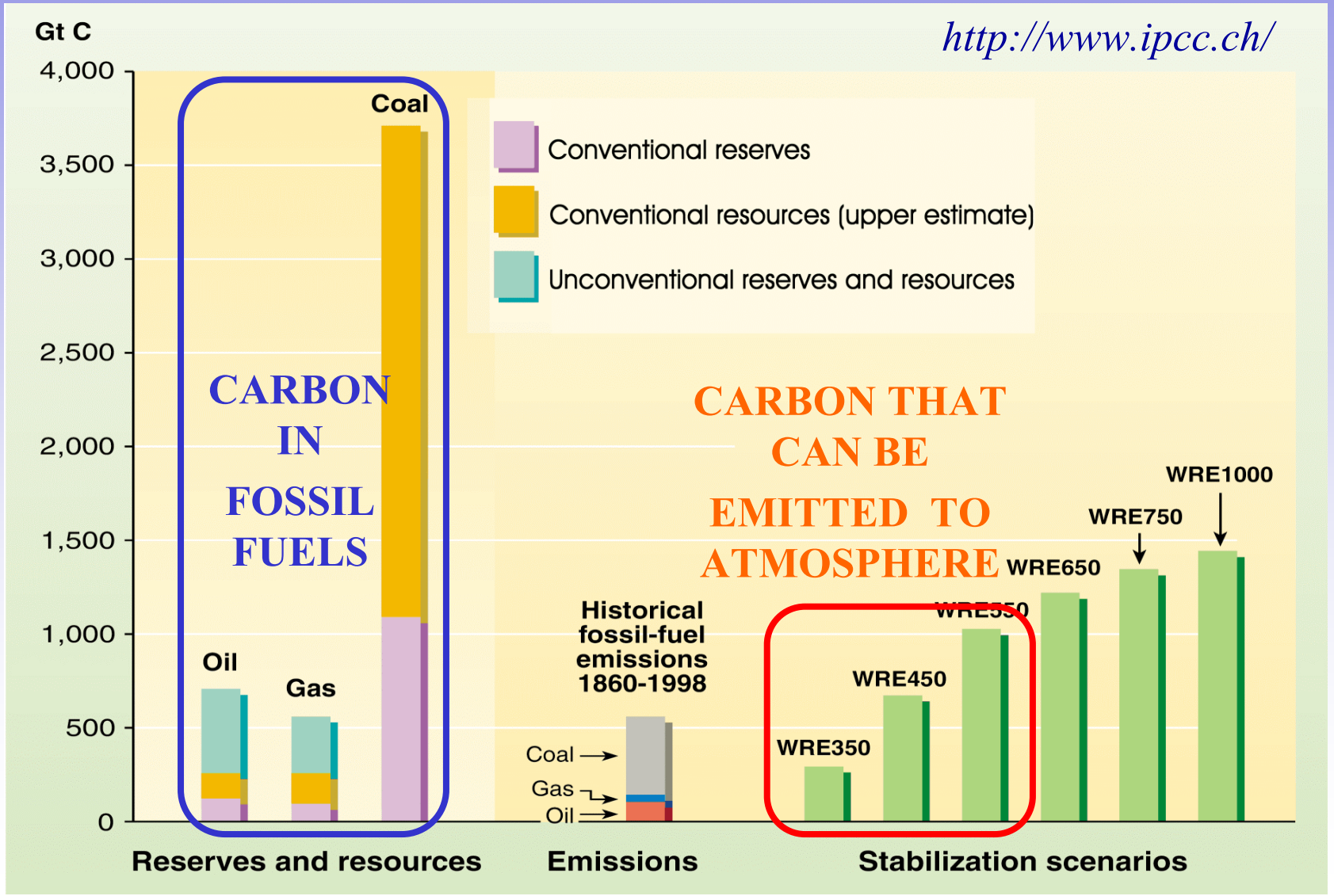
- variable capture level, venting CO_2
- variable capture penalty, full capture with solvent storage

WHEN

capture is added

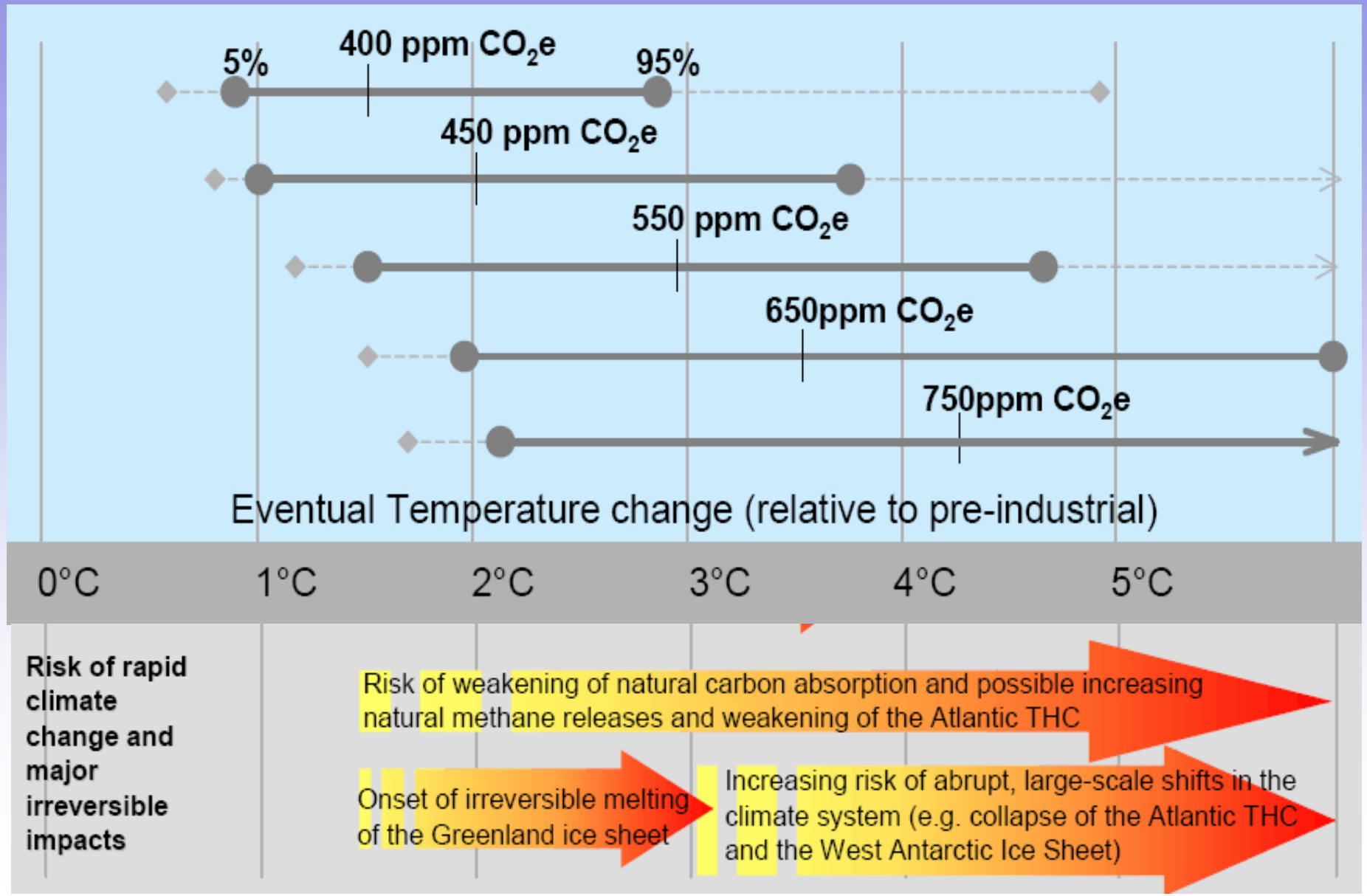
CRITICAL ROLE FOR CCS

'Unconventional oil' includes oil sands and oil shales. Unconventional gas' includes coal bed methane, deep geopressured gas etc. but not up to 12,000 GtC from gas hydrates.



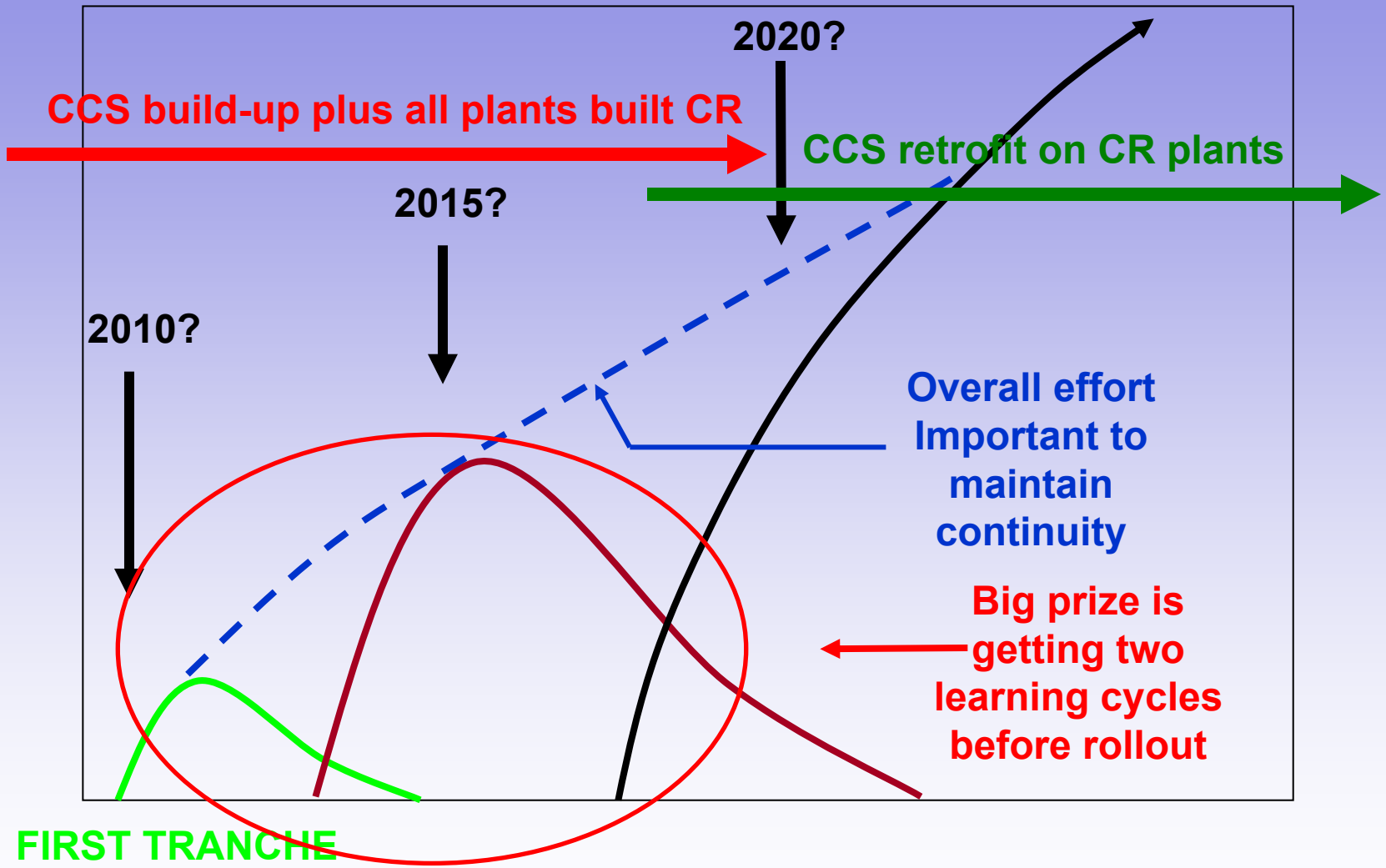
STERN REVIEW: The Economics of Climate Change

(already at 430 ppm CO_2e and currently rising at roughly 2.5 ppm every year)



BUILD-UP TO ZERO EMISSIONS FROM COAL

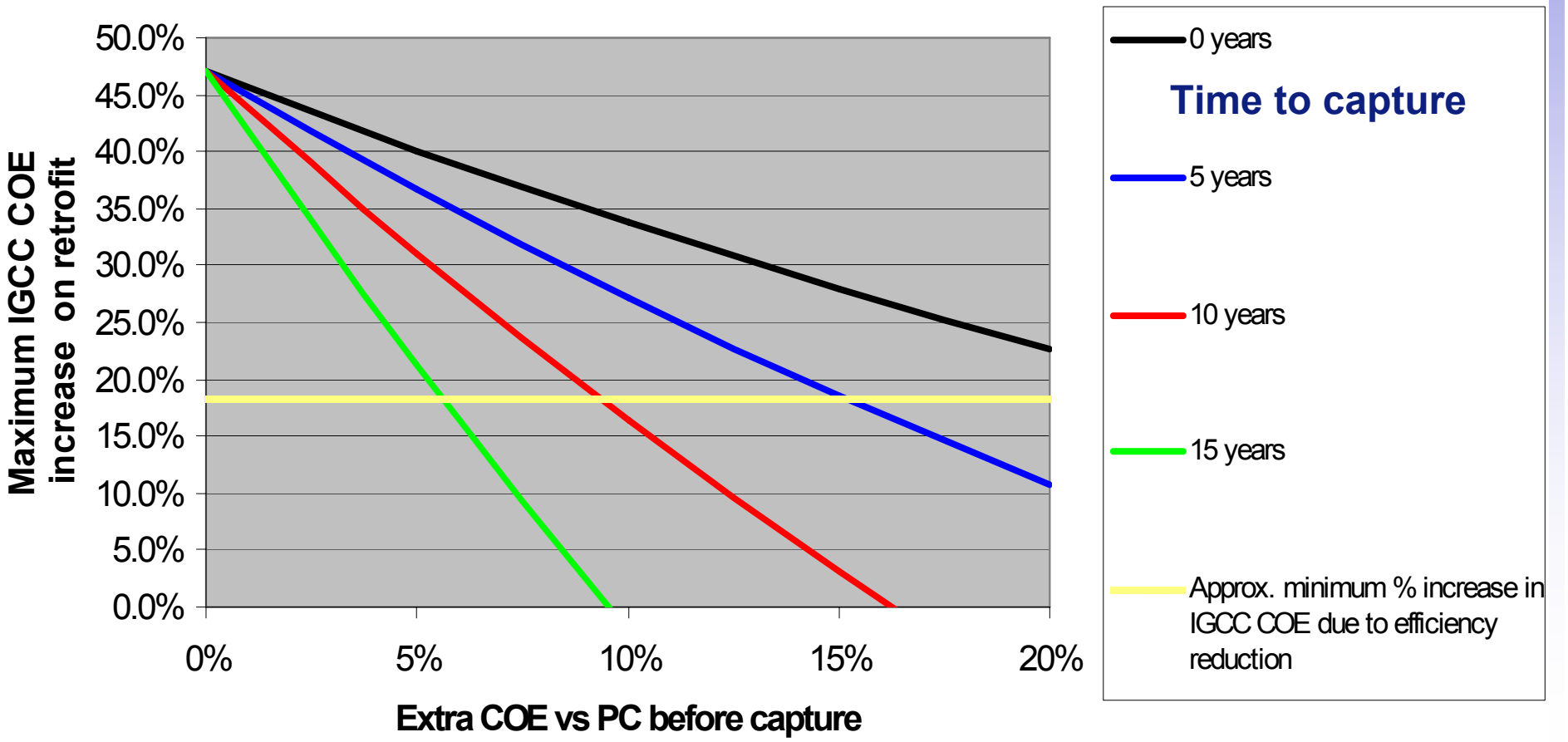
http://ec.europa.eu/energy/energy_policy/annexes_en.htm



BALANCING HIGHER INITIAL COSTS WITH LOWER CAPTURE COSTS FOR IGCC

Cost increase for CR PC 50%
Cost increase for new capacity vs PC 25%
CR PC Capture penalty 44% to 34.5% LHV
CR IGCC capture penalty 42% to 35.5% LHV

Interest rate 10%
Plant life 40 years

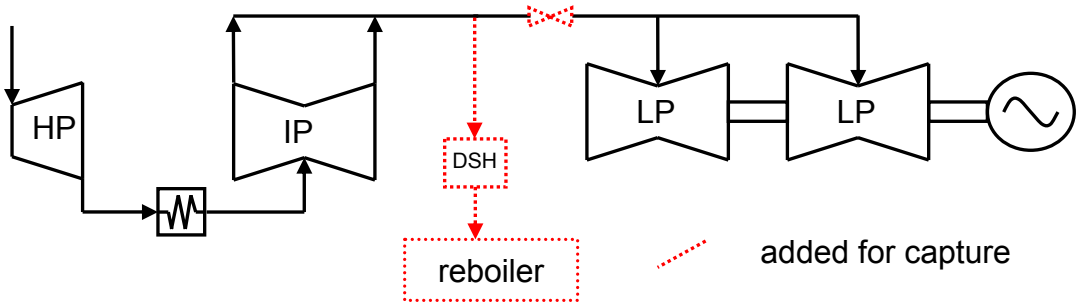


WHAT

capture technology can be added
flexible steam cycle

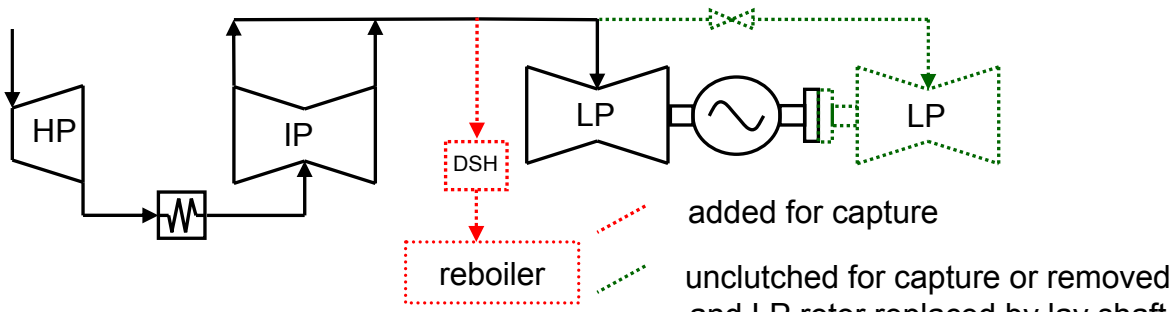
SINGLE UNIT CAPTURE-READY STEAM TURBINE DESIGNS

• Throttled LP turbine



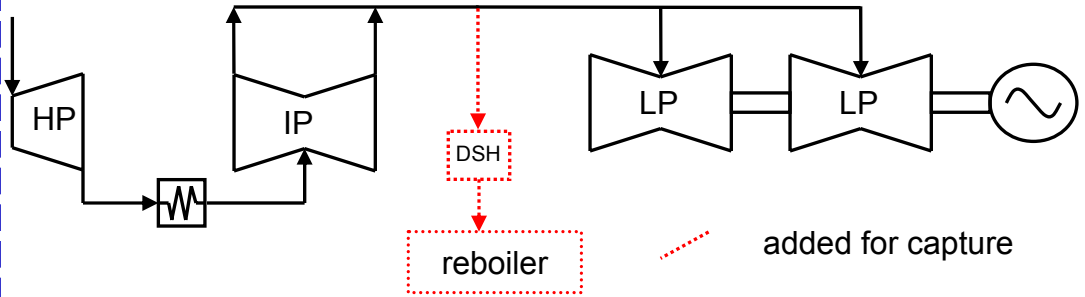
Simplest design, but losses in throttling valve. Initial pressure ~3.6 bar for amine, cannot be varied

• Clutched LP turbine



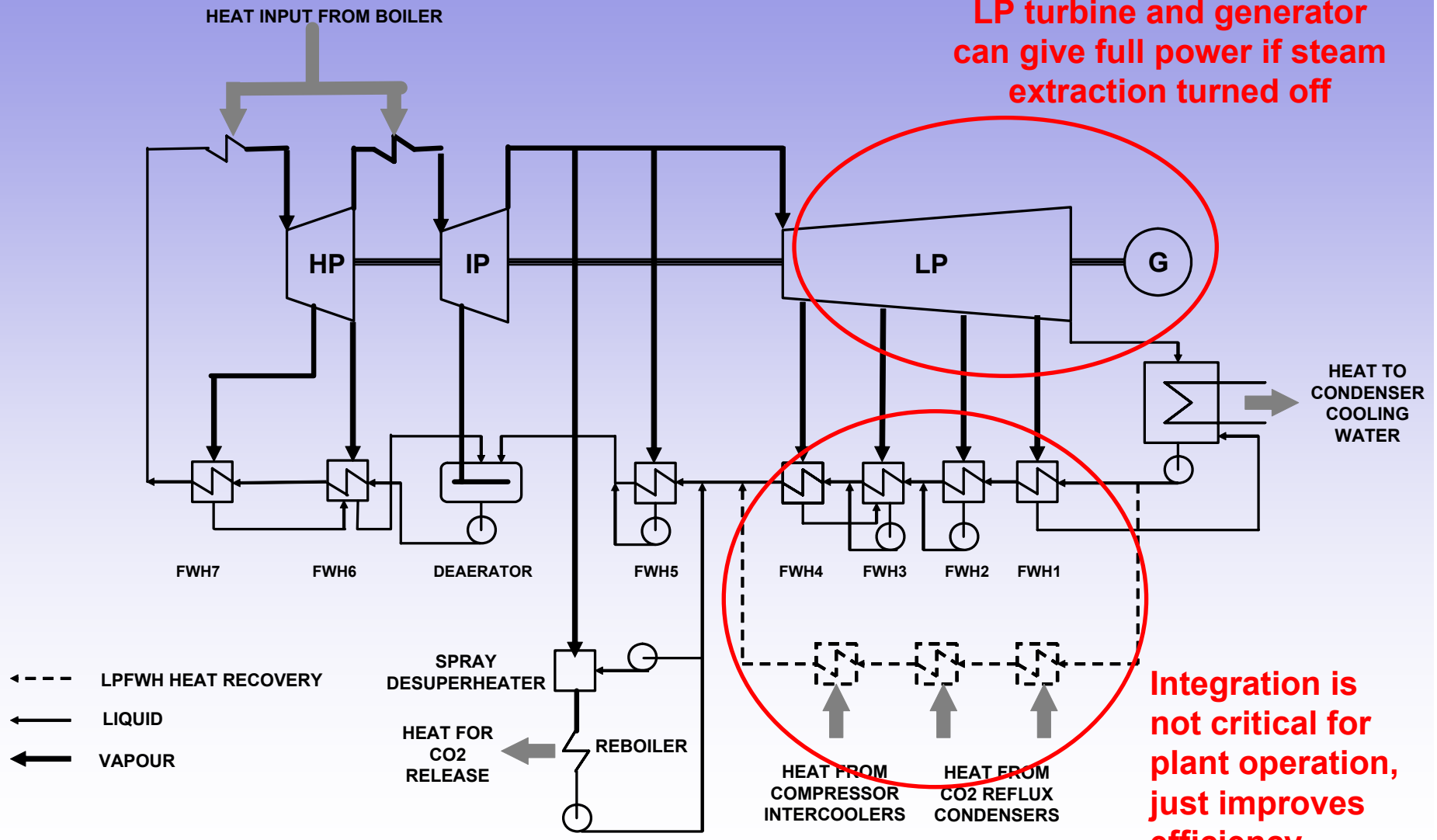
Most efficient design, but cannot vary steam extraction flow. Initial pressure ~3.6 bar for amine, cannot be varied

• Floating IP/LP crossover pressure

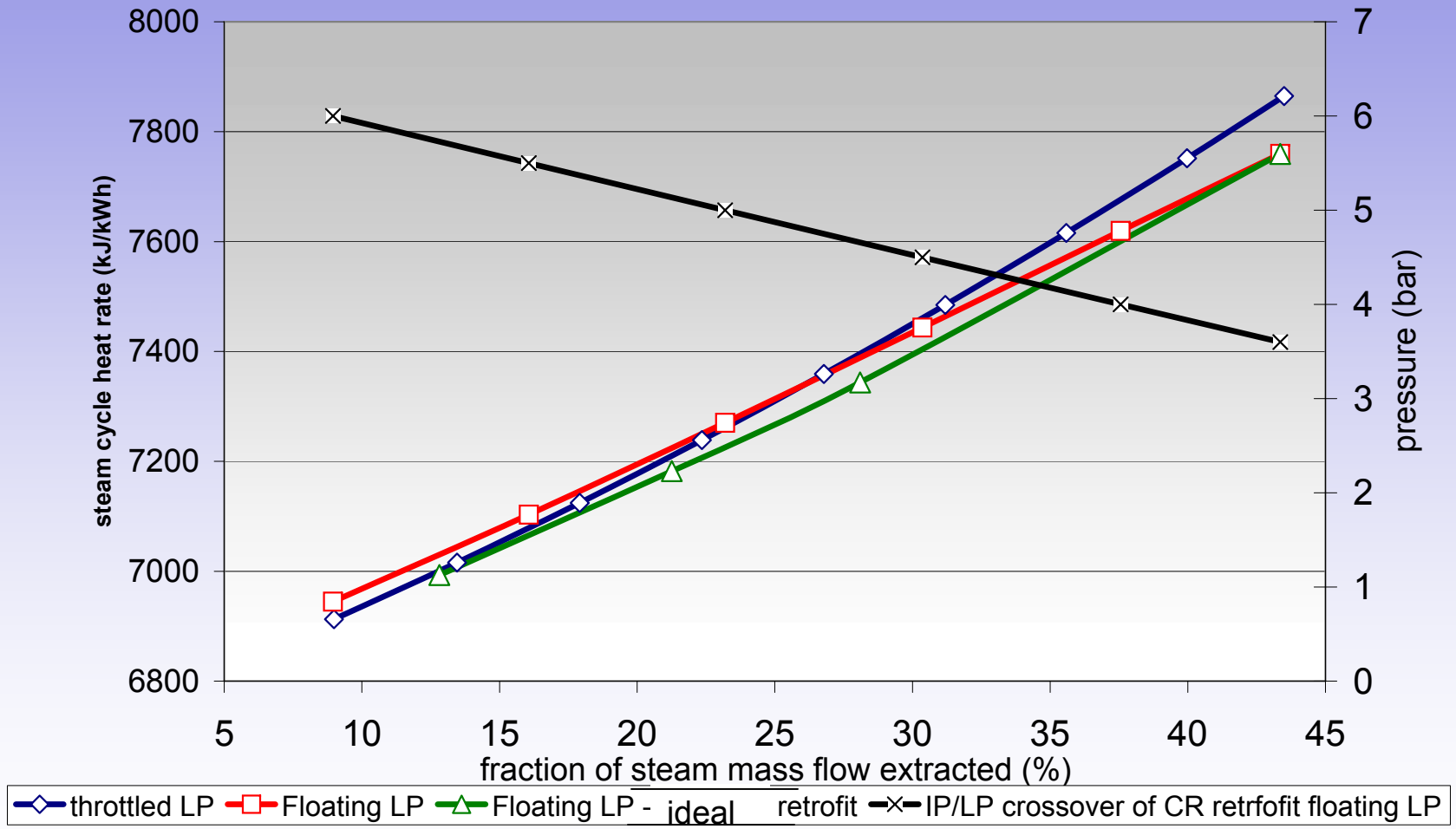


Avoids all throttling losses at design extraction rate. Extraction pressure goes up with reduced flow rate

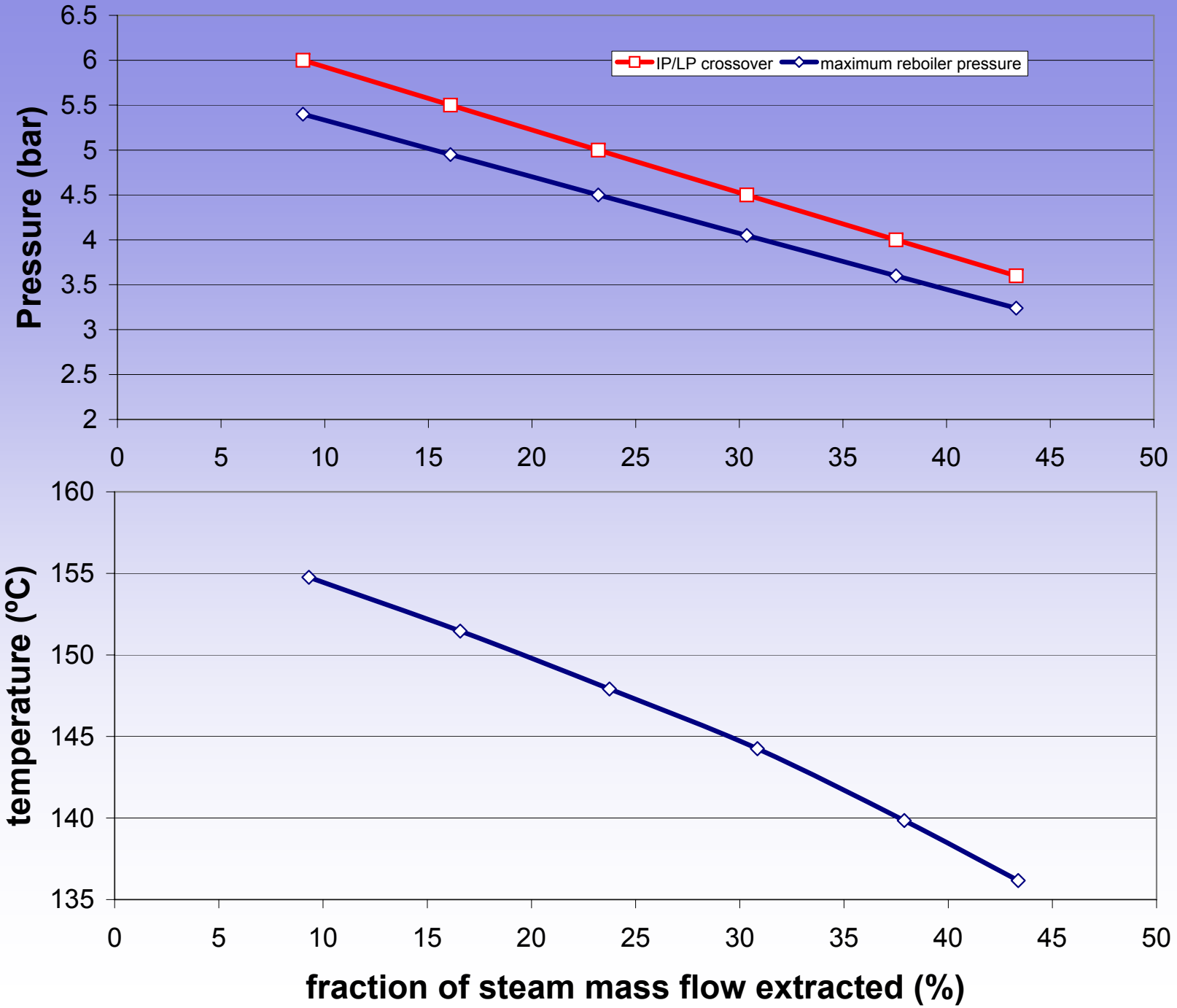
TYPICAL HEAT INTEGRATION OPTIONS FOR POST-COMBUSTION CAPTURE RETROFIT



RELATIVE HEAT RATES FOR THROTTLED LP AND FLOATING IP/LP OPTIONS



MAXIMUM PRESSURES AND TEMPERATURES FOR FLOATING IP/LP OPTION



HOW

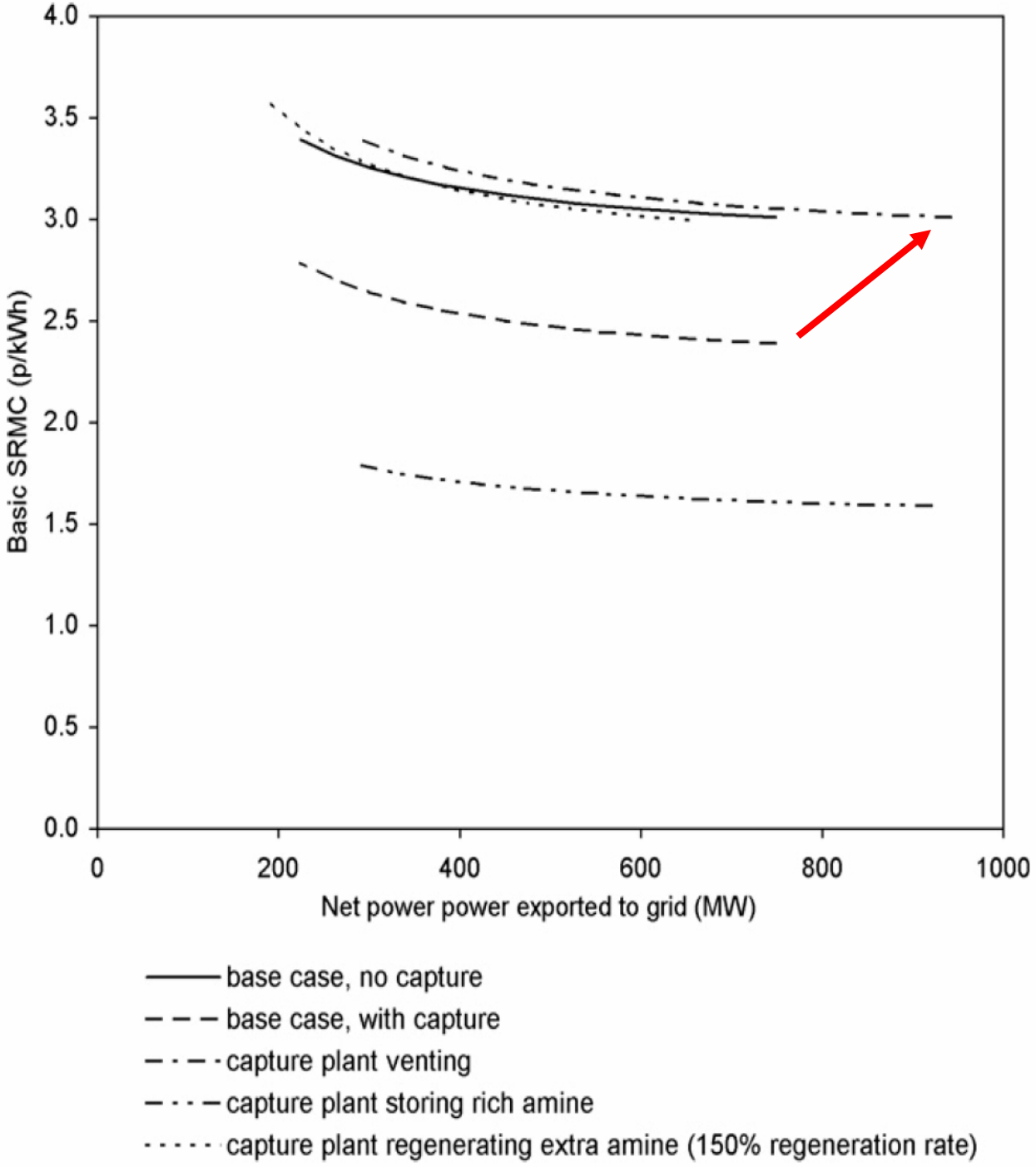
plant can be operated with capture

Flexibility of PC operation increased with CCS - arbitrage between carbon and electricity prices now possible

Note retrofitted PC plant probably won't naturally be baseload

Plant output	750 MW
Coal price	£1.4/GJ
Carbon price	£25/tCO_2
CO_2 transport & storage	£5.5/tCO_2

Chalmers H, Gibbins J, Initial evaluation of the impact of post-combustion capture of carbon dioxide on supercritical pulverised coal power plant part load performance, Fuel (2007) (in press)



Arbitrage between carbon and electricity prices for simply venting CO_2 to atmosphere

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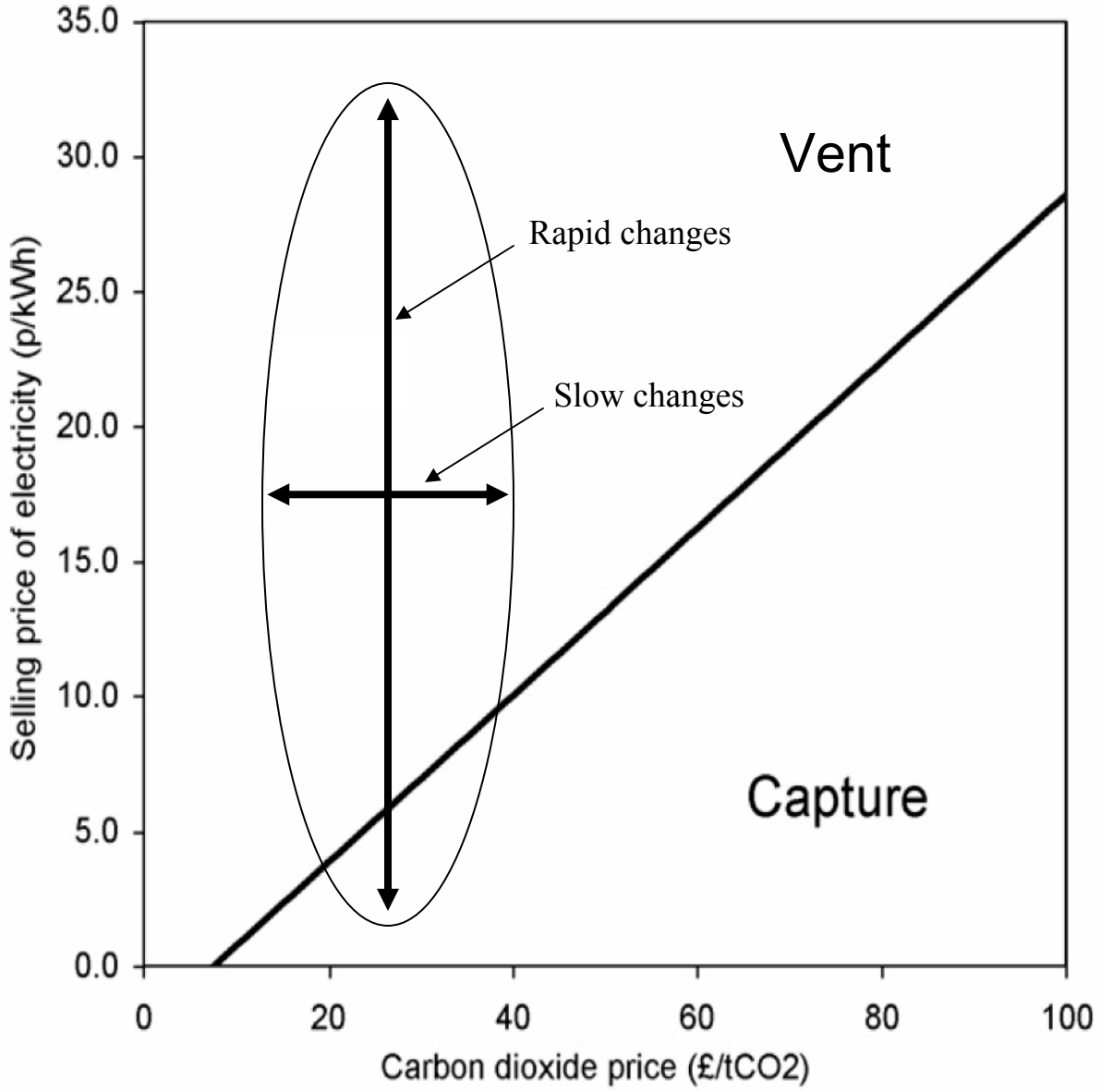

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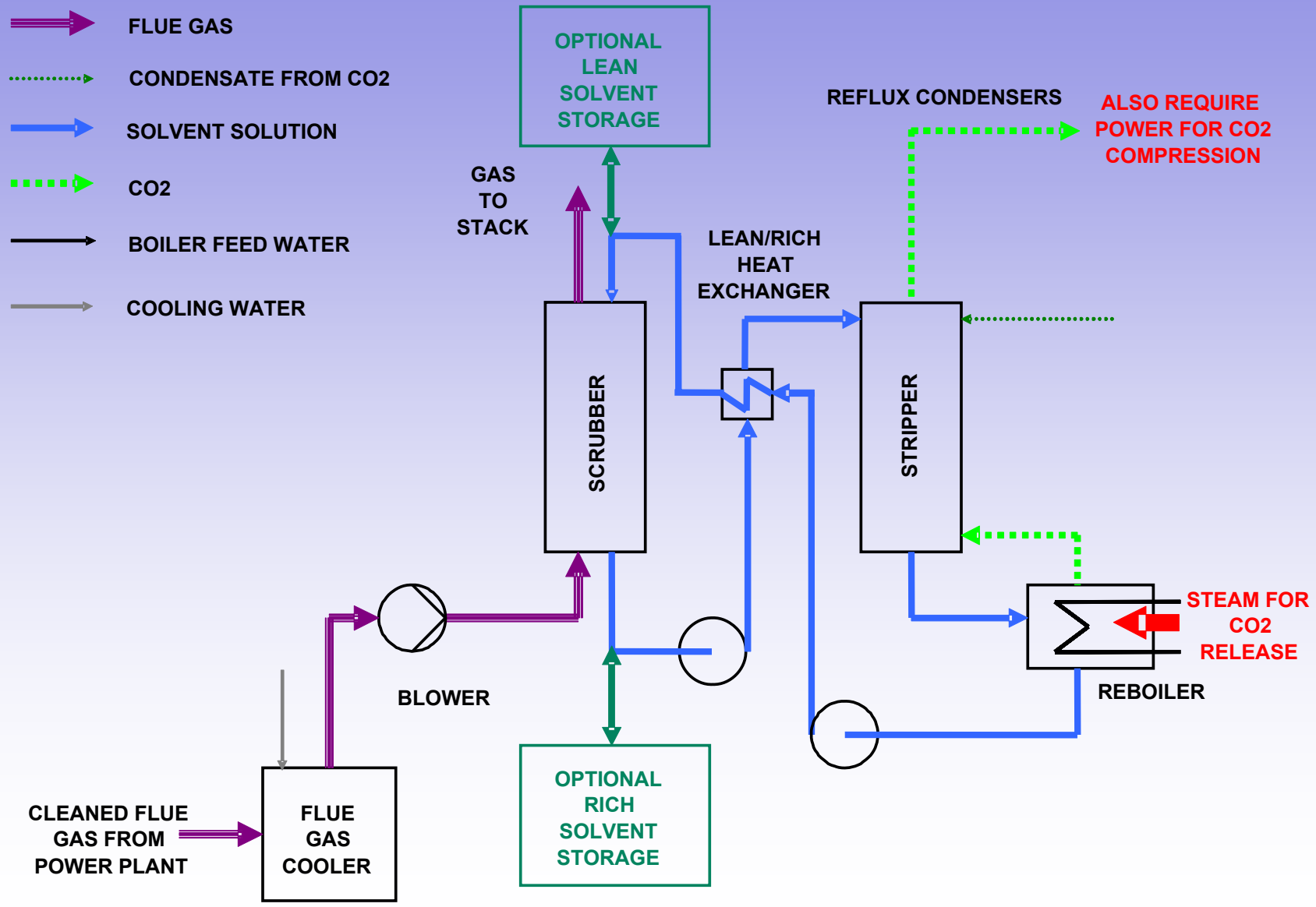
Post Combustion Capture Plant with Solvent Storage



Reduced output and short run marginal cost of generation for solvent storage – generate more when prices high, less when prices low, improve load factor for capital recovery

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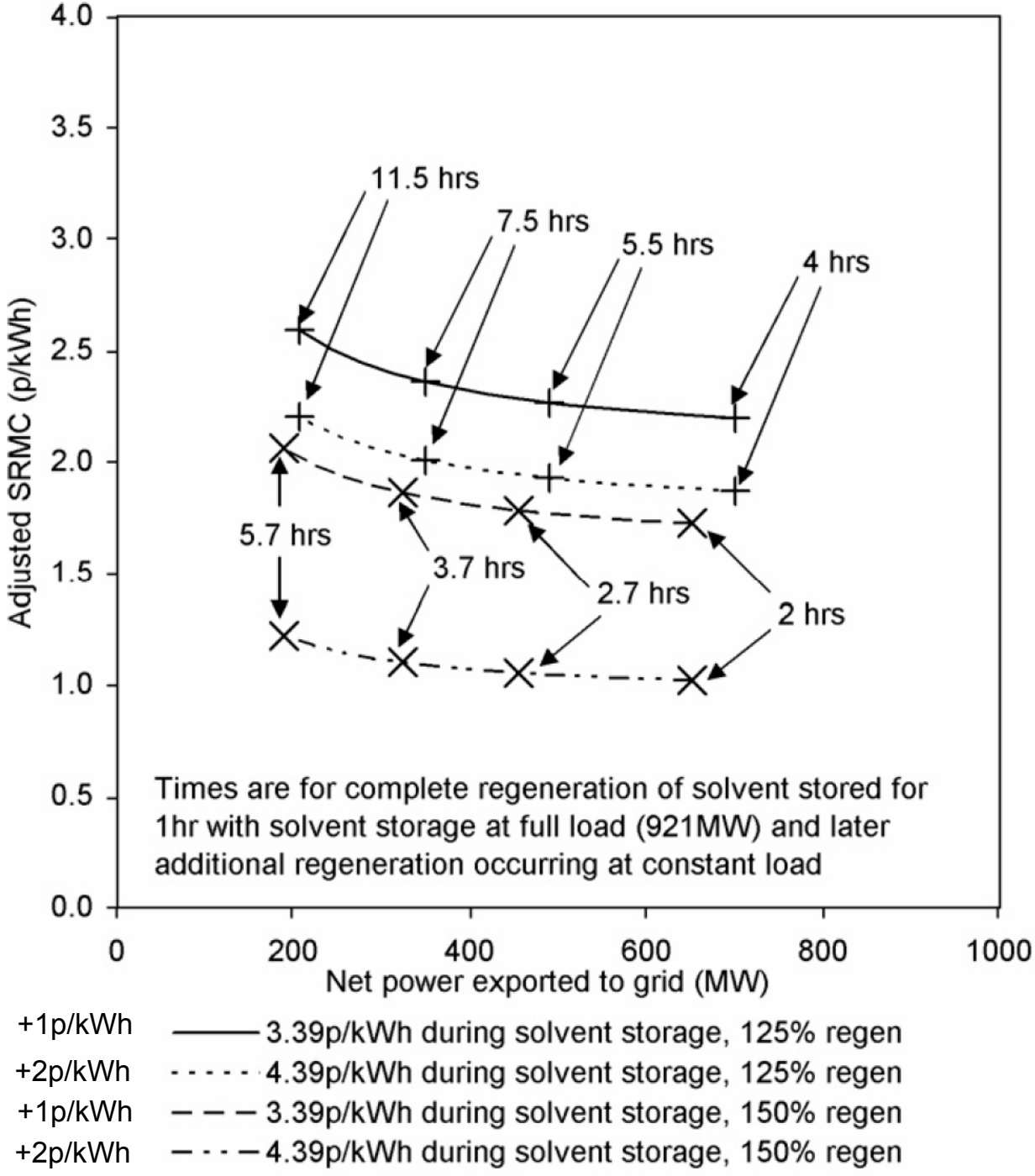
CO_2 transport & storage	£5.5/tCO2



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Conclusions

- **Capture-ready PC plant has a range of flexibilities:**
  - **a) When capture is added, timing not critical**
  - **b) What capture technology can be added**
  - **c) How plant can be operated with capture**
- **How can this be valued?**
- **Options valuation techniques available, Monte Carlo methods to get numbers but results still depend on unknown data**
- **Results also site/market specific**
- **But value of flexibility probably significant, even if not known exactly**
- **Value also depends critically on future costs and performance of post-combustion capture technologies**


CCS OR THE END!